The distribution, abundance and conservation status of riverine frogs in Kosciuszko National Park

David Hunter[1] **and Graeme R. Gillespie**[2]
[1]Applied Ecology Group, University of Canberra, P.O. Box 1, Belconnen, Australian Capital Territory 2616
[2]Arthur Rylah Institute, Department of Natural Resources and Environment, P.O. Box 137, Heidelberg, Victoria 3084

ABSTRACT

A survey was conducted of the distribution and abundance of stream-breeding frogs within Kosciuszko National Park, with particular emphasis upon locating new populations of the endangered Spotted Tree Frog *Litoria spenceri*. Twenty-five streams were sampled within the Park. Populations of *L. spenceri* were located on two streams, including one new locality for the species. This constitutes only the second population of this species known from New South Wales. Three other riverine species were located during the survey. The endangered Booroolong Frog *L. booroolongensis* was located only along one stream and could not be found at the two historic sites within the Park. The overall abundance of riverine frogs was found to be relatively low. Frogs were found at significantly fewer sites affected by modified stream flows from the Snowy Mountains Scheme, than comparatively undisturbed sites. The potential impacts of these changes and introduced fish upon the distribution and abundance of riverine frogs within the region are discussed.

Key words: *Litoria spenceri*, *Litoria booroolongensis*, Kosciuszko, Introduced trout, Declining amphibians, Hydrological impacts, Distribution, Conservation status, New South Wales.

INTRODUCTION

During the past two decades, populations of numerous amphibian species have declined or disappeared in Australia, particularly along the eastern sea board (Czechura and Ingram 1990; McDonald 1990; Osborne 1990; Richards *et al.* 1993; Hollis 1995; Gillespie and Hollis 1996; White and Pyke 1996; Tyler 1997). In many cases the cause(s) of these declines is unknown. Despite the increasing concerns generated by this phenomenon, knowledge of the distribution and conservation status of many frog species in Australia remains poor. This has hampered assessments of the extent or pattern of population declines. Such knowledge is vital for understanding the nature of observed declines, and for directing research into possible causal factors (Pechman *et al.* 1991; Pechman and Wilbur 1994). Accurate information on the current distribution of threatened species is also required for the development and implementation of effective management actions to maximize the protection of populations and recovery of species.

Riverine species in Kosciuszko National Park

Two significant species of riverine frog have been recorded in Kosciuszko National Park, the Spotted Tree Frog *Litoria spenceri* and Booroolong Frog *L. booroolongensis*. The Park provides important habitat for at least one of these species, *L. spenceri* (Gillespie and Hollis 1996). However, little is known about the distribution of riverine frogs in the area (Gillespie *et al.* 1995). *Litoria spenceri* has a limited and fragmented distribution, confined to streams predominantly on the north-west fall of the Great Dividing Range, from the Central Highlands of Victoria to Mount Kosciuszko in New South Wales, from 280 to 1 100 m (Watson *et al.* 1991; Gillespie and Hollis 1996). Extensive surveys of the distribution and abundance of *L. spenceri* between 1989 and 1995 revealed that substantial population declines have occurred. Only 12 discrete populations were believed to remain — 11 in Victoria and one in New South Wales (Watson *et al.* 1991; Gillespie and Hollis 1996). The species has been listed as Endangered nationally (ANZECC 1991, 1995).

The single population of *L. spenceri* in New South Wales occurs in Bogong Creek, Kosciuszko National Park. The density of this population was found to be far greater than that observed along any stream in Victoria (Gillespie and Hollis 1996) and, as such, is highly unusual and of high conservation significance.

Few surveys incorporating frogs have been conducted below the sub-alpine zone in Kosciuszko National Park. Since the known historic range of *L. spenceri* was restricted predominantly to Victoria, survey effort for the species was limited in New South Wales to streams in the vicinity of Bogong Creek and the Victorian border (Watson *et al.* 1991; Gillespie and Hollis 1996). Gillespie and Hollis (1996) surveyed six sites from three streams; Leatherbarrel Creek, Three Rocks Creek and the Geehi River. Ehmann *et al.* (1993) reported visiting nine sites on five streams in search of *L. spenceri*; however, the localities were not disclosed. In view of the large population of *L. spenceri* located in Bogong Creek, there is the possibility that other populations might occur in potentially suitable streams along the western fall of Kosciuszko National Park.

The known southern limit of *L. booroolongensis* is within Kosciuszko National Park, in the Tumut River catchment (New South Wales Wildlife Atlas; Australian National Wildlife Collection, CSIRO, Australian Capital Territory). This species was historically widespread in the northern tablelands of New South Wales (Heatwole *et al.* 1995). However, searches in recent years have failed to locate the species in this area, and it has been seen infrequently in the southern tablelands (M. Mahony, Applied Science Department, University of Newcastle, pers. comm. 1997; F. Lemckert, State Forests, New South Wales, pers. comm. 1997). Consequently *L. booroolongensis* was recently listed as Endangered in New South Wales (NSW NPWS Scientific Committee Determination Advice No. 97/27). The species was last recorded in Kosciuszko National Park in 1987 (Australian National Wildlife Collection # A1671 and A1672).

A morphologically distinctive form of the Leaf-green Tree Frog *L. phyllochroa* was recently discovered in the Cotter River in the Australian Capital Territory (Gillespie and Osborne 1994). This population is currently considered conspecific with southern populations of *L. phyllochroa* (S. Donnellan, South Australian Museum, pers. comm. 1996). However, it is geographically disjunct; other *L. phyllochroa* populations known within the region are restricted to Bogong Creek and the Mitta Mitta River catchment in Victoria (Gillespie and Hollis 1996). The taxonomic and conservation significance of the Cotter River population, and the status of *L. phyllochroa* on the western fall of the Great Dividing Range are currently unclear.

Potential threats to riverine frogs

Probably the most significant ecological changes to have occurred in streams within the Snowy Mountains in the last 100 years are introduced fish and impacts from the Snowy Mountains Hydroelectric Scheme.

Introduced trout have been identified as a potential cause of decline of *L. spenceri* (Watson *et al.* 1991). Studies overseas have demonstrated that fish are highly effective predators of tadpoles, and have the potential to eliminate species which lack defences against predation in some habitats (Heyer *et al.* 1975; Petranka *et al.* 1987). The impact of introduced trout on amphibians has been demonstrated in Europe and North America (Burger 1950; Macan 1966; Hayes and Jennings 1986; Bradford 1989; Bradford *et al.* 1993; Bronmark and Edenhamn 1994). Trout have been widely introduced throughout the Kosciuszko region (McDowall 1996).

Disturbance of riparian habitats has been correlated with the decline of *L. spenceri* (Gillespie and Hollis 1996). Many of the streams within Kosciuszko National Park have been significantly modified by the Snowy Mountains Hydroelectric Scheme. This has been in the form of modifications to water flow regimes, habitat destruction through building dams, roads and other infrastructure, and facilitation of weed and feral animal invasion.

The impacts of introduced trout and disturbances to stream habitats upon amphibian populations within the Kosciuszko region are unknown. Both these changes may adversely affect riverine amphibian assemblages.

Objectives

Improved knowledge of the distribution of riverine frogs within the Kosciuszko National Park will aid in assessing the conservation significance of some populations, and assist in development of appropriate conservation and management plans for threatened species. The objectives of this study were to determine the distribution and relative abundance of riverine frogs on the western fall of Kosciuszko National Park, with particular emphasis on locating populations of *L. spenceri*. The occurrence of fish is also documented. The current population status of riverine species within the region is assessed. The distribution and abundance of frogs is also examined in relation to the occurrence of introduced fish and major hydrological modifications to streams.

METHODS

Study area and site selection

The study was confined to the western fall of Kosciuszko National Park as this area contains all of the potentially suitable habitat for *L. spenceri* in New South Wales (as described by Gillespie and Hollis 1996), and because *L. booroolongensis* is known only from the western side of the Divide in southern New South Wales (New South Wales Wildlife Atlas).

Five major catchments flow off the western fall: the Upper Murray, Swampy Plains, Tooma, Tumut and Goodradigbee. Topographic maps (1:50 000) were used to choose streams which incorporated a range of stream sizes, distributed across these major catchments.

Sites were selected which exhibited broad habitat characteristics similar to those described by Gillespie and Hollis (1996), i.e., rocky riffle habitats with steep banks. This was achieved by choosing stream sections with relatively steep gradients and narrow riparian terraces. Some streams with extensive suitable habitat were surveyed at more than one locality. Many of the streams in the study area have been modified to varying degrees by aqueduct intakes and pondages for the Snowy Mountains Hydro-electric scheme. Where possible, sites were chosen both above and below these structures. The distance between sites on the same stream varied considerably, depending upon availability of access. In most cases sites were at least several kilometres apart. In some cases, such as on Bogong Creek and the Murray River, sites were contiguous but separated by notable geographic features or habitat disjunctions, such as large waterfalls or aqueducts and impoundments. All historical site localities of riverine species were surveyed. Two sites in the headwaters of the Snowy River catchment were also surveyed, due to their proximity to the Upper Murray catchment.

Survey techniques

A minimum of 1 km was surveyed at each site, with the exception of a few sites where the habitat was considered unsuitable, or where time was limiting. The survey technique used followed that of Gillespie and Hollis (1996). Search effort at each site was measured by distance searched rather than time searched (after Gillespie and Hollis 1996), as search time per unit distance along streams varied enormously due to logistical and habitat variability. Sampling was conducted in January-February 1996, and December-January 1996/97. All sites were surveyed diurnally when the stream was exposed to the sun; usually between 10.00 am and 4.00 pm. Surveys were conducted during mild to warm conditions on sunny days. Previous searches for *L. spenceri* by the authors and others (Watson *et al.* 1991; Hero *et al.* 1995; Gillespie and Hollis 1996) indicate that these are the optimal times and conditions for detecting most of these riverine species. Searches were restricted to the immediate stream environment and along the banks. Crevices under loose rocks and in bedrock were investigated for sheltering animals. Ferns and sedges, and rocks near the water's edge, were investigated for basking individuals.

Night surveys were also conducted on a number of streams to augment the diurnal surveys. These were only conducted on nights with suitably mild weather conditions (air temperature >10°C), which limited the number of sites surveyed. Night censuses were mainly conducted in the northern section of Kosciuszko National Park where there was a strong focus on locating *L. phyllochroa* (a more nocturnal species) and *L. booroolongensis*. This involved surveying a minimum of 300 m of stream at night using head torches to spotlight for frogs in adjacent habitat. At each site the numbers of frogs of each species were counted.

Visual searches for tadpoles and fish were conducted along each reach surveyed. Tadpole surveys were focused primarily on slow-flowing stream sections and stream-side pools which are typical microhabitats for the riverine species (Hero and Gillespie 1993; Hero *et al.* 1995; Anstis *et al.* 1998). Any tadpoles encountered were captured using a small aquarium net, and the species identified (from Hero and Gillespie 1993; Hero *et al.* 1995).

The presence or absence of fish species was recorded at each site. Rainbow Trout *Oncorhynchus mykiss* and Brown Trout *Salmo trutta* occur in streams throughout Kosciuszko National Park, but it was not practical to distinguish them visually. Likewise no attempt was made in the field to distinguish between the two species of galaxias which occur in the region: the Mountain Galaxias *Galaxias olidus* and Climbing Galaxias *G. brevipinnis*.

Data analysis

Comparison between the occurrence of riverine frogs and the presence of major flow modification structures associated with the Snowy Mountains Scheme was examined by contingency table analysis. This was performed for *L. lesueuri* but the other riverine species were not found at enough sites for individual analysis. Consequently data on all riverine species were pooled and examined collectively. The proportion of sites at which frogs were detected was compared for stream reaches below impoundments and those not affected by structures. Only major structures which have resulted in an observable modification of stream flow at sampling sites, such as dams and aqueducts, were considered. Two sites sampled were along major water courses which had an aqueduct well up-stream in the headwaters. These sites were classed as "unmodified" for the purposes of analysis, as stream flows at the sites were considered to be near-natural due to incoming unmodified tributaries below the aqueducts. To minimize effects of non-independence, sites within 2 km of each other on the same stream were considered as single samples.

Altitude is known to influence the distributions of many amphibians (Osborne 1989;

Duellman and Trueb 1994). Riverine species may be restricted by altitude to upper or lower reaches of streams. Sites sampled below impoundments could potentially have a lower altitudinal range than those typically occupied by frogs. Altitudinal constraints on the distribution of frogs along streams could therefore confound interpretation of the effects of stream impoundments on frog occurrence. Impoundment effects can only be distinguished from altitude effects if the altitudinal range of sample sites does not vary in relation to occurrence of frogs or up-stream impoundments. This was tested by using a two way analysis of variance to examine differences in mean altitude between sites affected by impoundments and those unaffected, and occurrence of frogs. The mean altitude of stream reaches sampled was used as the dependent variable; presence/absence of frogs and presence/absence of up-stream hydrological impoundments were used as factors. Altitude was log-transformed to meet assumptions of normality and equal variance.

Comparison of the occurrence of riverine frogs and introduced fish was not analysed statistically because there were too few sites at which introduced fish were not detected.

RESULTS

A total of 43 sites were surveyed along 25 streams, covering 57 km of water course (Fig. 1; Table 1). Frogs were located at 22 of these sites, along 15 streams. Six frog species were recorded during the survey.

Species distribution and abundance

A new population of *L. spenceri* was located on the Murray River (Fig. 1; Table 1). One sub-adult frog was found basking on a rock next to a riffle section, in December 1996. The stream section was surveyed again in February 1997 but no more *L. spenceri* were located.

The Bogong Creek population was found to be restricted to a relatively short section of stream. High numbers of *L. spenceri* (130 per km) were found along a section of water course 1.6 km in length (site 36). This extended from below an aqueduct intake for the Snowy Mountains Hydroelectric Scheme, through Bourke's Gorge, to a large waterfall (>4 m high). Numerous tadpoles were also observed in pools throughout this section of water course. A further 3.8 km of stream was surveyed below the waterfall; however, few frogs were located. One adult *L. spenceri* was located and tadpoles were found in a disconnected streamside pool between this waterfall and another, 300 m downstream. Below the second waterfall only two frogs were found. These were at the same locality, on a pebble bank, 1.5 km further down-stream. No *L. spenceri* were detected at the historic locality on Bogong Creek at the Alpine Way (site 37).

Litoria booroolongensis was only located on one stream. The species was found along one section of the Goobarragandra River. This is a new locality for the species. Despite surveying eight sites from four streams in the Tumut catchment (Table 1) this was the only record of a riverine frog for this system. The survey failed to locate *L. booroolongensis* in the Tumut or Yarrangobilly Rivers. *Litoria booroolongensis* had previously been recorded in these streams (sites 6 and 11, Table 1) (New South Wales Wildlife Atlas; Australian National Wildlife Collection, CSIRO, Australian Capital Territory).

Litoria phyllochroa was located on five streams: the upper Murray, Swampy Plains, and Goodradigbee Rivers, and Lady Northcote and Bogong Creeks (Table 1). The population on the Goodradigbee River exhibited similar morphological features to the population in the Cotter River (brown dorsum with numerous raised warts). *Litoria phyllochroa* was not located on the two other streams surveyed in the Goodradigbee catchment: Peppercorn Creek and Coleman Creek.

Lesueur's Frog *L. lesueuri* was the most frequently encountered and most widespread species (Table 1, Fig. 2). It was recorded at 15 localities along 13 streams, in the Goodradigbee, Swampy Plains, Murray, and Snowy catchments (Table 1).

Two lentic species, Whistling Tree Frog *L. verreauxii* and the Pobblebonk Frog *Limnodynastes dumerilii* were recorded along streams during this survey. *Litoria verreauxii* was recorded on the Geehi River and Yarrangobilly River. *Limnodynastes dumerilii* was recorded along the Goodradigbee River.

Frogs were not located at 21 of the sites surveyed (Table 1). No frogs were located in any streams in the Tooma system (Table 1). Furthermore, the relative abundance of frogs (number per km) recorded along most streams was low (Table 1). Exceptions to this were populations of *L. spenceri* on Bogong Creek (Bourke's Gorge), *L. phyllochroa* on the Goodradigbee River and *L. lesueuri* on the Murray River (Table 1). However, most *L. lesueuri* located on the Upper Murray River were recently-metamorphosed juveniles. Frogs were located in all major catchments except for the Tooma.

Tadpoles were only detected along seven of the streams surveyed. At most sites where

Table 1. Localities and streams surveyed, search effort (km) with numbers of each frog species located, and fish species observed. + — Recorded on this survey # — Nocturnal and diurnal survey conducted. T — Tadpoles located. x — Previously recorded in stream (McDowall 1996; Lintermans and Rutzou 1990; M. Lintermans, Australian Capital Territory Parks and Conservation Service, Unpubl. data; New South Wales Wildlife Atlas; Museum Records). * — Aqueduct in upper catchment; site considered to have minimal flow modification.

				Australian Map Grid Ref.		Altitude (m)			Frog species						Fish species				
Site	Stream (Catchment in bold)	Date	Map Sheet	(lower)	(upper)	(lower)	(upper)	Distance searched (km)	*L. booroolongensis*	*L. lesueuri*	*L. phyllochroa*	*L. spenceri*	*L. verreauxii*	*L. dumerilii*	Trout spp.	*Perca fluviatilis*	*Galaxias* spp.	*Gadopsis bispinosis*	Dams and aquaducts
	Goodradigby																		
1	Goodradigbee R.#	2/17/96	8627	565707	568701	740	750	1.0		3	16			1	+			x	A*
2	Peppercorn Ck.	2/17/96	8627	565707	558706	740	780	1.1		2					+				
3	Cooleman Ck.#	2/23/96	8627	555576	544748	670	710	1.1		8					+				
	Tumut																		
4	Tumut R.	1/31/96	8526	229206	226199	860	900	1.0							x	+		x	D
5	Tumut R.	1/31/96	8526	243187	237181	1030	1050	0.9							+			x	D
6	Tumut R.	3/1/97	8526	229340	228341	550	550	0.3	x						+	x		x	D
7	Goobarragandra R.#	2/21/96	8627	370384	382766	570	620	2.2							+			+	
8	Goobarragandra R.#	2/15/97	8627	402756	409750	820	840	0.8							+			x	
9	*Goobarragandra R.#*	11/29/96	8627	362782	370785	540	570	1.0	9						+		x	x	
10	Yarrangobilly R.#	2/22/96	8526	342446	341459	870	880	1.5							+				
11	Yarrangobilly R.#	2/21/96	8526	316533	323536	995	1005	0.8	x				1		+				
12	Peak R.#	2/11/97	8527	288741	286749	630	650	0.9							+				
	Tooma																		
13	Deep Ck.	1/23/96	8525	185139		860	1200	3.1							+		+		A
14	Ogilives Ck.	1/23/96	8525	189147		900	960	0.4											A
15	Ogilives Ck.	2/1/96	8525	194136		1240	1290	0.4											A
16	Yellow Bog Ck.	1/24/96	8525	075076	081065	940	1080	1.1											
17	Yellow Bog Ck.	1/24/96	8525	082144	089137	580	640	1.1							x				
18	Tooma R.	1/29/96	8525	163114	160110	1080	1100	0.5							x			x	D,A
	Swampy Plains																		
19	Khancoban Ck.	1/26/96	8525	052917	064924	400	460	1.7		2					+				A
20	Khancoban Ck.	2/5/96	8525	061949	057962	700	770	1.8							+				
21	Swampy Plains Ck.	1/27/96	8525	064701	071678	480	660	3.6		7T	2T				+		x	+	
22	Swampy Plains Ck.	2/26/96	8525	069651	069639	840	940	1.2							+			x	
23	Bridge Ck.	1/27/96	8525	055701	052698	470	480	0.4											
24	Geehi R.	1/28/96	8525	188832	189840	1140	1160	2.0		1					+		x	x	
25	Geehi R.	2/3/96	8525	152778	165786	850	950	1.0					2		+			x	D
26	Geehi R.	2/24/96	8525	211863	218872	1320	1420	1.3							+			x	
27	Geehi R.	2/25/96	8525	125746	131752	610	630	0.9		1T					+		x	x	D
28	Kosciuzko Ck.	2/2/96	8525	092737	097727	500	620	1.2							+		+		
29	Three Rocks Ck.	2/3/96	8525	166787	168782	940	980	0.5									+		A
30	Broken Back Ck.	2/4/96	8525	076895	087898	600	650	1.0		3					+				
31	Lady Northcote Ck.	2/7/96	8525	139729	140718	940	1180	1.1									+		A
32	Lady Northcote Ck.	2/25/96	8525	126748	134741	620	760	1.3		1T	T				+		+		A
33	Bogong Ck.	2/13/96	8525	109833	122849	780	880	2.5				2			+				A
34	Bogong Ck.	2/14/96	8525	122849	125857	880	960	1.0							+				A
35	Bogong Ck.	2/14/96	8525	125857	126860	960	990	0.3				1T			+				A
36	Bogong Ck.	2/14/96	8525	126860	126865	990	1120	1.6			10T	120T					+		A
37	Bogong Ck.	2/18/96	8525	078757	074762	480	490	1.0		T	6T	x						+	A*
	Murray																		
38	Leatherbarrel Ck.	1/25/96	8524	060551	068569	880	990	2.8							+			+	
39	Murray R.	1/2/97	8524	978278	992263	840	900	3.2		17T		1			+			+	
40	Murray R.#	2/28/97	8524	988270	992263	900	1000	1.6		>100T	3T				+			+	
41	Tin Mine Ck.#	1/4/97	8524	719076	401094	720	820	2.8		1					+			+	
	Snowy																		
42	Jacobs R	1/1/97	8524	270349	275340	320	360	1.0		T					+				
43	Pinch Ck.	1/1/97	8524	237278	229285	260	280	1.2		T					+				

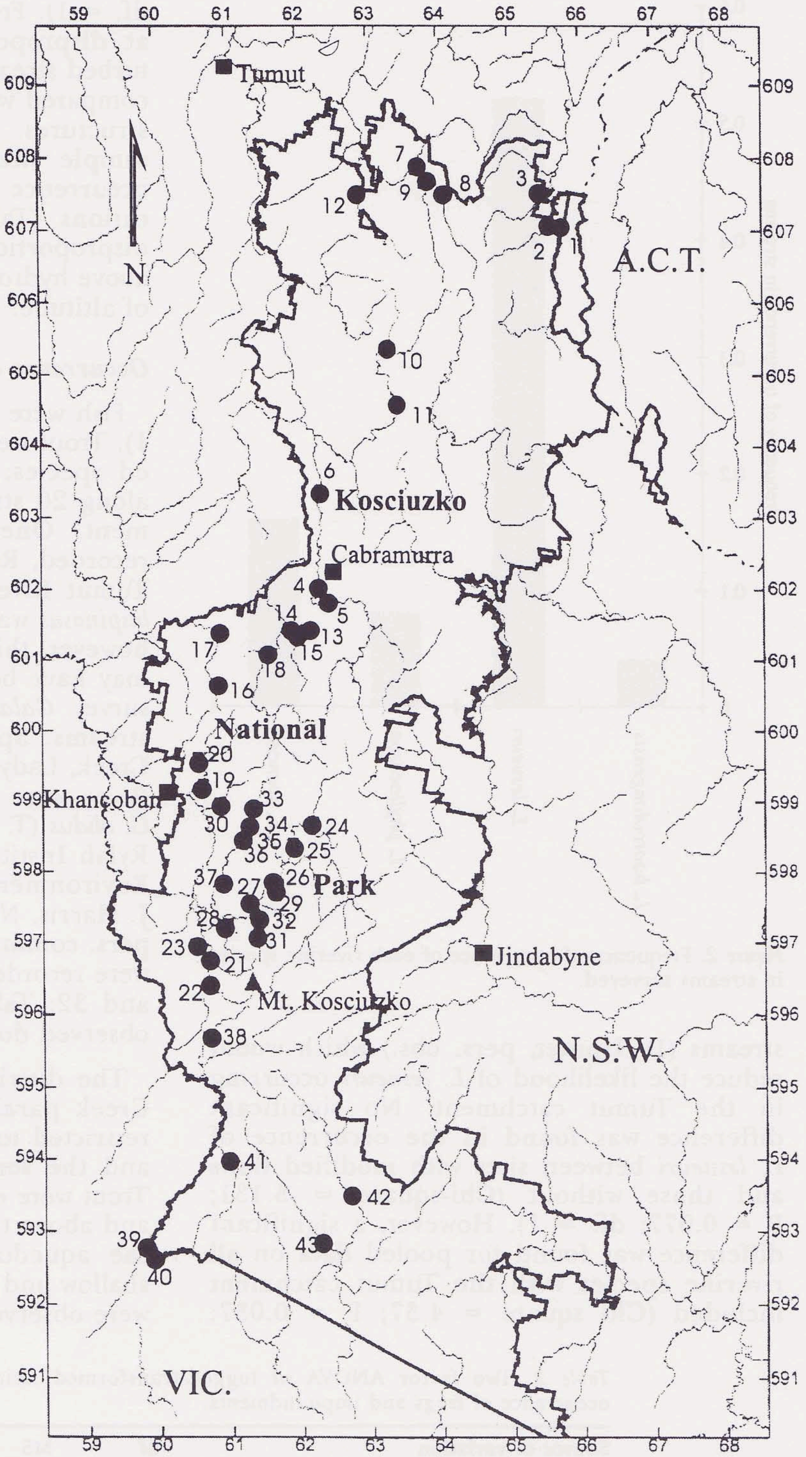


Figure 1. Localities sampled in Kosciuszko National Park during this survey (closed circles).

tadpoles were located, adults of the species were also found. There were only four sites where a species was only detected by the presence of tadpoles: *L. phyllochroa* on Lady Northcote Creek (site 32); and *L. lesueuri* on Bogong Creek, Jacobs River and Pinch Creek (sites 37, 42 and 43).

Hydrological changes on frog occurrence

Contiguous sites on three streams were collated for examination of the distribution of riverine frogs and the occurrence of major flow modification structures (sites 7 and 9; 33–36; 39 and 40; Table 1). One site (No. 26) was excluded as it is considered to be above the known altitudinal limit of the riverine species (see Gillespie and Hollis 1996; Anstis *et al.*, in press). Sites in the Tumut catchment were not included in analysis of *L. lesueuri* occurrence because of the presence of *L. booroolongensis* in this system. These species may be allopatrically distributed along

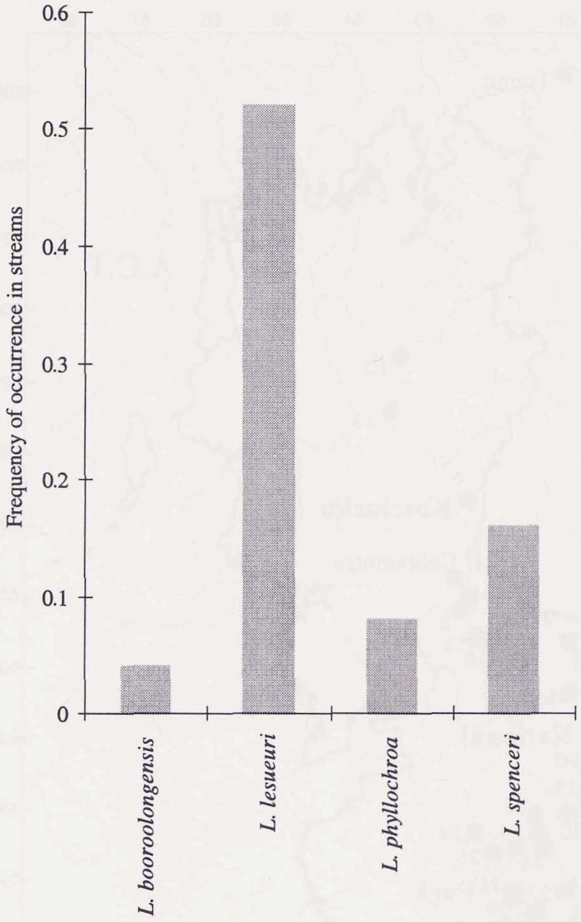


Figure 2. Frequency of occurrence of each riverine species in streams surveyed.

streams (D. Hunter, pers. obs.) which would reduce the likelihood of *L. lesueuri* occurring in the Tumut catchment. No significant difference was found in the occurrence of *L. lesueuri* between sites with modified flows and those without (Chi-square = 3.131; P = 0.077; df. = 1). However, a significant difference was found for pooled data on all riverine species with the Tumut catchment included (Chi square = 4.37; P = 0.037; df. = 1). Frog species collectively were found at disproportionately more sites in undisturbed streams or above dams and aqueducts, compared with those down-stream from these structures. The mean altitudinal range of sample sites did not vary significantly by occurrence of frogs or hydrological modifications (Table 2). This indicates that the disproportionate occurrence of frogs at sites above hydrological structures is not an artifact of altitude.

Occurrence of fish

Fish were observed along 21 streams (Table 1). Trout were the most commonly encountered species; they were recorded at 31 sites along 20 streams, and in every major catchment. One other introduced species was recorded, Redfin Perch *Perca fluviatilis*, in the Tumut River. Two-spined Blackfish *Gadopsis bispinosus* was recorded along only six streams; however, this species is relatively cryptic and may have been easily overlooked during this survey. *Galaxias* spp. were recorded from five streams. Specimens collected from Bogong Creek, Lady Northcote Creek and the Murray River were identified as Mountain Galaxias *G. olidus* (T. Raadic, Freshwater Section, Arthur Rylah Institute, Dept. Natural Resources and Environment, Victoria, pers. comm. 1997; J. Harris, New South Wales Fisheries, Sydney, pers. comm. 1998). Where trout and galaxias were recorded in the same stream (sites 13, 28 and 32; Table 1), the trout were invariably observed down-stream of the galaxias.

The distribution of galaxias along Bogong Creek parallelled that of *L. spenceri*, being restricted to the reach between the aqueduct and the series of large waterfalls (site 36). Trout were observed both below the waterfalls and above the aqueduct. The stream between the aqueduct and the falls was relatively shallow and the water was very clear; no trout were observed in this section.

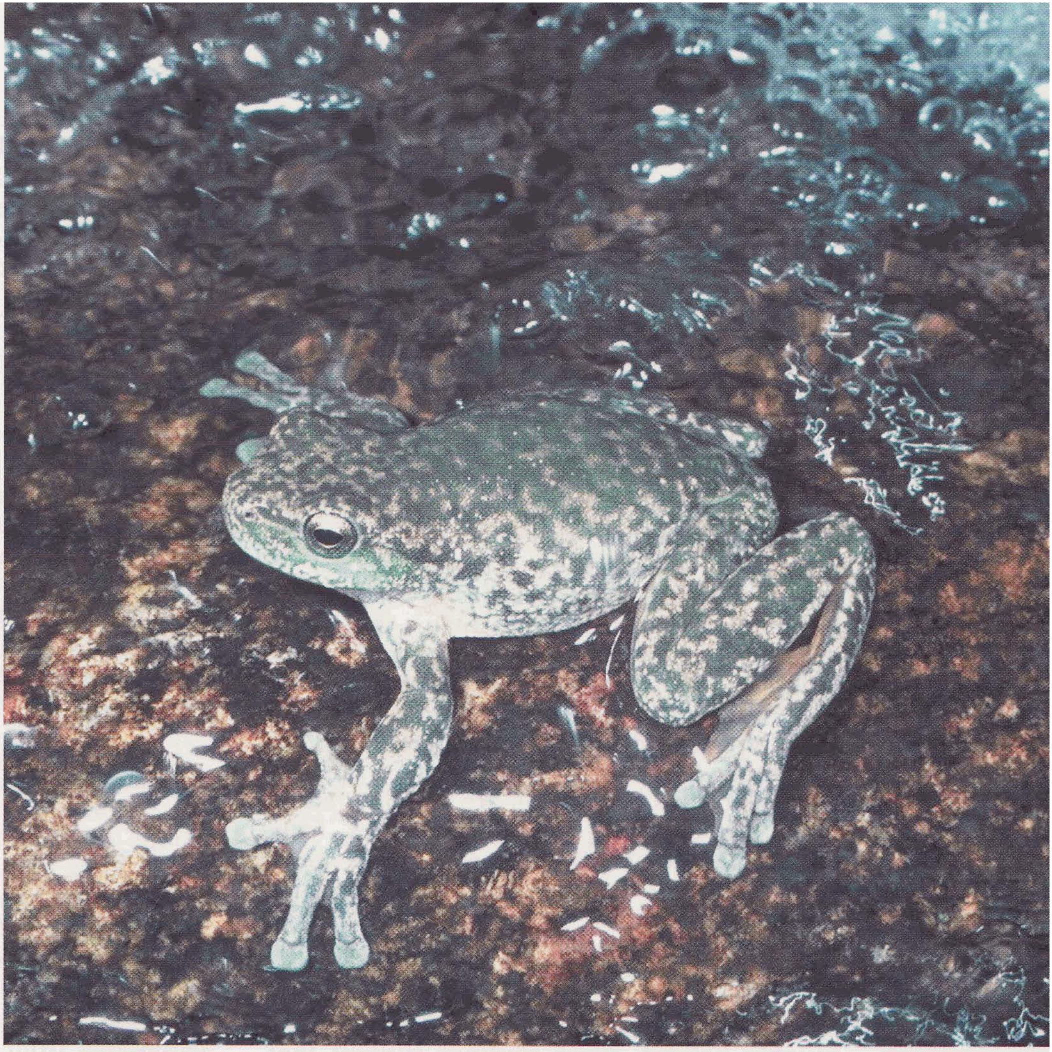
Table 2. Two factor ANOVA of logged-transformed altitude of survey sites by occurrence of frogs and impoundments.

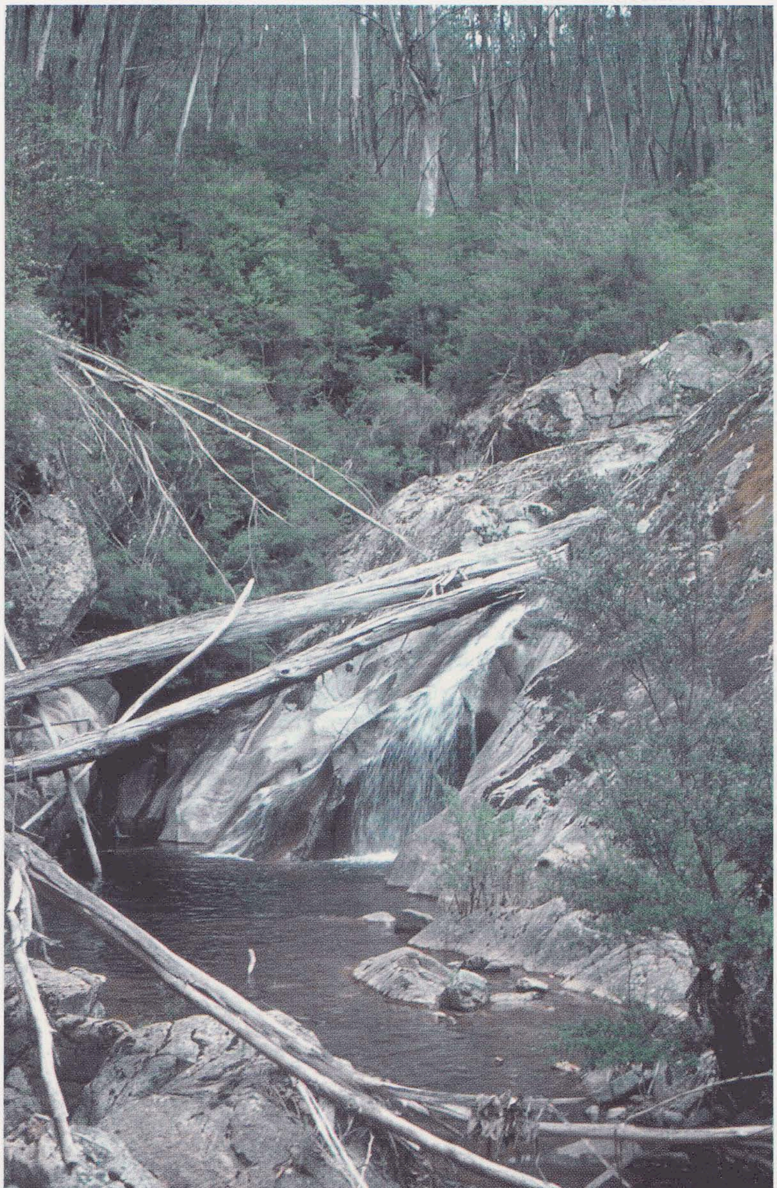
Source of variation	df	MS	F	*p*
Occurrence of impoundments	1	0.004	0.055	0.816
Occurrence of frogs	1	0.148	2.00	0.167
Impoundments * frogs interaction	1	0.093	1.259	0.270
Residual	31	0.074		
	LS Mean	S.E.	n	
Impoundments absent	6.607	0.058	22	
Impoundments present	6.635	0.104	13	
Frogs absent	6.705	0.058	22	
Frogs present	6.536	0.104	13	
Impoundments and frogs absent	6.624	0.082	11	
Impoundments absent; frogs present	6.589	0.082	11	
Impoundments present; frogs absent	6.786	0.082	11	
Impoundments and frogs present	6.483	0.192	2	

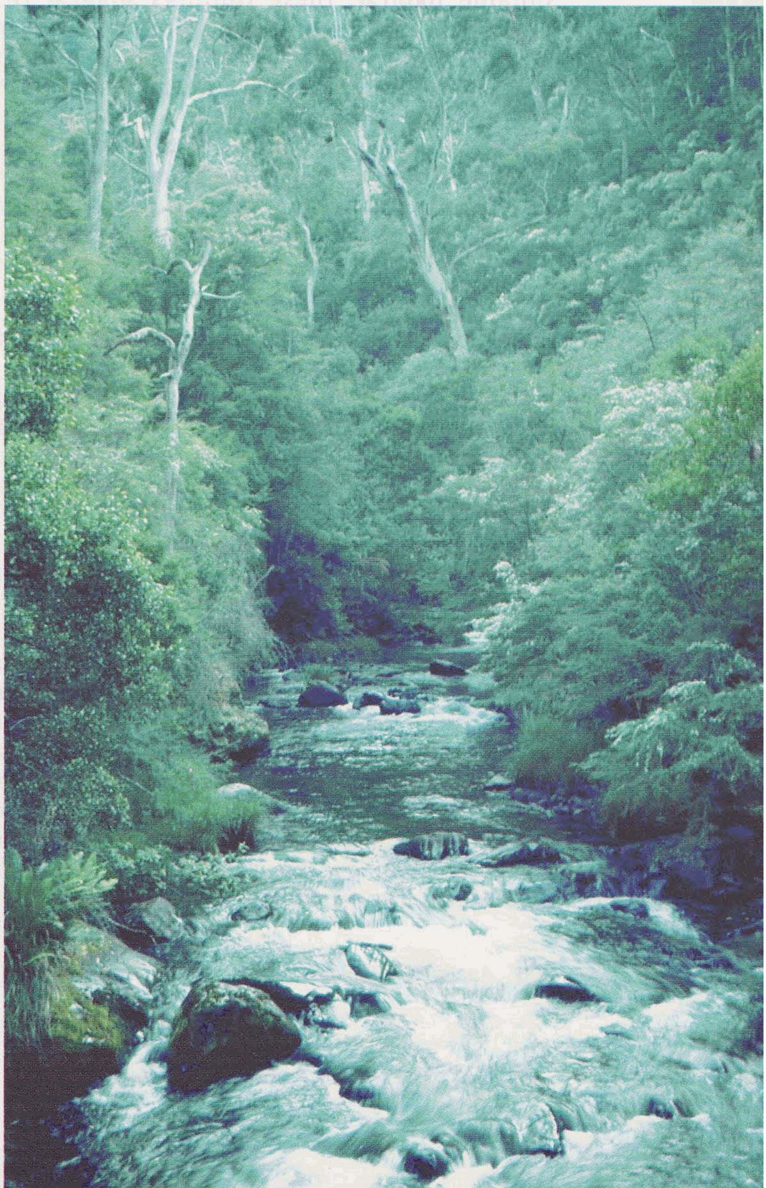
Right: Litoria spenceri, Bogong Creek, Kosciuszko National Park. Photo: G. Gillespie.

Bottom left: Bogong Creek, Kosciuszko National Park. Photo: G. Gillespie.

Bottom right: Bogong Creek, Kosciuszko National Park. Photo: G. Gillespie.







DISCUSSION

Species distribution and relative abundance

The discovery of another population of *L. spenceri* on the upper Murray River was not entirely unexpected. This stream lies between extant populations of *L. spenceri* in adjacent river basins in Victoria (Wheeler Creek and Mitta Mitta system) and Bogong Creek in New South Wales (Gillespie and Hollis 1996). Nevertheless this discovery is a major extension of the occurrence of *L. spenceri* in New South Wales, and contributes significantly to the overall conservation status of the species. *Litoria spenceri* is restricted to the upper reaches of catchments, so the frogs in different streams constitute discrete isolated populations. This new population in the Murray River is one of only 13 extant populations known. The detection of only one individual and no tadpoles on the upper Murray suggests that the density and size of this population are very low, based upon surveys and density estimates from Victorian streams (Gillespie and Hollis 1996; Gillespie 1997). As with many of the remaining populations of *L. spenceri*, this population may be restricted to only a small section of the catchment.

Despite the presence of extensive seemingly suitable habitat, these findings suggest that *L. spenceri* may only occur along two streams in New South Wales, Bogong Creek and the Murray River. It was not possible to survey the entire length of streams. Consequently some populations may have been overlooked. However, the most likely places were all examined, based upon known habitat associations. Any additional populations are therefore likely to be very small and restricted in distribution.

The population of *L. spenceri* along Bogong Creek was found to be restricted to a discrete section of stream only 1.6 km long. The relative abundance of frogs detected was similar to that recorded along this section by Gillespie and Hollis (1996) who found 69 individuals. *Litoria spenceri* was first discovered on Bogong Creek approximately 15 km further down-stream, at the Alpine Way bridge (site 29; Table 1) in 1975 (Watson *et al.* 1991), but has not been seen at this site since, despite numerous searches (Watson *et al.* 1991; Ehmann *et al.* 1993; Gillespie and Hollis 1996; Gillespie 1997; this study). Despite this contraction, the remaining population has persisted at much higher densities than anywhere else throughout the current range of the species. A density of 75 individuals/km was recorded during this survey. Gillespie and Hollis found 69/km at this site but less than 29/km at all other sites in Victoria. This stream reach is therefore of high conservation value for the species and of great interest for examining factors currently limiting the species' distribution and abundance.

The occurrence of *L. booroolongensis* in the Goobarragandra River constitutes a new locality for this species in the Southern Highlands and confirms its persistence in the Tumut catchment. The findings of this survey and Gillespie and Hollis (1996) suggest that the Tumut system constitutes the southern limit of *L. booroolongensis*. Failure to detect *L. booroolongensis* in the Tumut catchment where it has previously been recorded is of concern, in light of the population declines reported elsewhere in its range. This new population is therefore considered to be of high conservation significance.

Litoria phyllochroa was relatively uncommon compared to other parts of the species' range on the eastern fall of the Great Dividing Range (G. Gillespie, pers. obs.). The Cotter River form of *L. phyllochroa* was restricted to the Goodradigbee River, which is adjacent to the Cotter River. The typical southern form of *L. phyllochroa* was restricted to the Murray and Swampy Plains catchments in the south of the Park. The absence of *L. phyllochroa* from both the intervening Tooma and Tumut catchments constitutes a substantial disjunction in the distribution of this species. The morphological distinctiveness of the Goodradigbee and Cotter River populations may be the result of past foundering effects and the current relative isolation of these populations. *Litoria phyllochroa* is less active by day than at night (Gillespie 1997), and may be more readily detected during nocturnal censuses. As a limited number of nocturnal censuses were conducted during the survey, the distribution of this species may have been underestimated.

The wide distribution of *L. lesueuri* observed in Kosciuszko National Park is consistent with observations by Gillespie and Hollis (1996), who found the species to be widespread in north eastern Victoria. However, the species was usually recorded in low abundance during this survey. The high number recorded on the Murray River (63/km) were mostly recently metamorposed individuals. The highest density of adults detected was 7.3/km on Cooleman Creek. This may have been due to some individuals leaving the immediate stream environment after the breeding season at the end of December. Reductions in relative abundance of adult *L. lesueuri* along streams in mid-summer have been documented in northeastern Victoria (Gillespie 1997). The species has also been located on wet nights on ridges and upper slopes, several hundred metres from streams, in late summer at the time of year when most survey work was conducted (G. Gillespie, pers. obs.). However, populations of *L. lesueuri* would usually still be detectable at this time of year by the presence of tadpoles, which are typically conspicuous in stream-side pool habitats. Despite this, tadpoles were only detected on seven streams.

The overall low numbers of each riverine frog species throughout the survey region (<6 individuals/km surveyed) is of concern. This may be explained in part by species such as *L. spenceri* and *L. booroolongensis* reaching their geographic limits of distribution, and historic biogeographical disjunctions in the distribution of *L. phyllochroa* within the region. However, this does not explain the low abundance of most of the populations of frogs which were recorded. In particular, *L. lesueuri* and *L. phyllochroa* are typically much more abundant along streams elsewhere in their ranges in southern Australia (Gillespie and Hollis 1996; Holloway 1997; Atlas of Victorian Wildlife). Declines have been documented for at least two species within the region: *L. spenceri* on lower Bogong Creek, and *L. booroolongensis* on the Tumut River. Declines in riverine frog populations may have been more widespread, and affected the other species as well. However, it is not possible to assess this, since historic data on the occurrence of frogs are absent from all other sites surveyed.

Impact of the Snowy Mountains Scheme

Dams and aqueducts associated with the Snowy Mountains Scheme have resulted in significant flow reductions, removal of peak flows, and in some cases unseasonal flow increases. These changes to stream flows could adversely affect riverine amphibians in several ways.

Reduced flows during natural peak flow periods allows build up of sediments and colonization of the stream channel by vegetation. Increased entrained sediments may reduce availability of oviposition sites and refugia for larvae. Encroachment of vegetation may reduce basking sites for adult frogs, and lower stream temperatures, which may reduce larval growth. If flows are reduced such that streams cease flowing, then larvae of most species are likely to be adversely affected by desiccation and elimination of breeding habitat. Increased flows during the warmer months, between November and February, may have severe adverse impacts upon temperate riverine amphibians. Significant rises in water level and velocity during this period are likely to flush eggs and larvae. Reduced water temperature of sub-surface releases from dams during the summer months is likely to inhibit larval growth and development.

The findings of this survey indicate that riverine amphibians have generally been adversely affected by modified stream flows resulting from the Snowy Mountains Scheme. Interestingly the occurrence of *L. lesueuri* by itself was not significantly affected. *Litoria lesueuri* is a widespread species which occupies a much broader range of habitats than the other species examined (Hero and Gillespie 1993; Barker *et al.* 1996; Gillespie and Hollis 1996; Anstis *et al.* 1998). It appears to be relatively tolerant of disturbances to stream habitats (Gillespie and Hollis 1996). *Litoria lesueuri* is able to breed in isolated stream-side lentic pools as well as the lotic environment (Anstis *et al.* 1998), suggesting a more general reproductive strategy. This species may therefore be more resilient to changes in streams brought about by the Snowy Mountains Scheme.

Many of the sites surveyed near or below hydro structures were grossly disturbed as a result of construction and road works. For instance the banks of the Tumut River at the historic localities for *L. booroolongensis* are infested with willows and blackberries, and high levels of sediment were visible in the stream at the time of the survey. Construction of the Blowering and Talbingo Dams has inundated much of the suitable habitat for *L. booroolongensis* along the Tumut River and significantly modified flow regimes downstream. Gillespie and Hollis (1996) found significant correlations between the decline of *L. spenceri* and the level of anthropogenic disturbances to catchments and riparian habitats. The disappearance of *L. booroolongensis* from this stream may be attributed to these high levels of habitat modification. These disturbances in concert with hydrological changes to streams may also have had an adverse affect on populations of riverine frogs in the region.

Impact of introduced fish

Introduced trout are widespread throughout river systems within Kosciuszko National Park. They have been recorded in nearly all streams surveyed. The impact of trout upon native *Galaxias* spp. has been well documented (McDowall 1968; Tilzey 1976; Jackson 1981; McIntosh and Townsend 1995). Observations of the restricted distribution of *Galaxias* spp. made during this survey are consistent with those of Tilzey (1976) and Jackson (1981), who found that *G. olidus* were generally restricted to waters inaccessible to trout above waterfalls.

The pattern of occurrence of *L. spenceri* in Bogong Creek is consistent with trout having had a major negative impact upon the distribution of this species. The section of Bogong Creek where *L. spenceri* occur in abundance is inaccessible to trout. The waterfalls at the down-stream end of the population are not negotiable to up-stream movement of trout. Rainbow Trout occur above the aqueduct intake up-stream (pers. obs.); however, access down-stream by these individuals is restricted to peak flows at the end of winter when some are washed over the aqueduct wall. Repeated observations during summer months between 1993 and 1998 by the authors suggest that those which survive do not appear to remain above the waterfalls over summer when tadpoles are present, due to the low water levels (pers. obs.). The abundance of *G. olidus* in this section of Bogong Creek, paralleling that of *L. spenceri*, is further testimony to the absence of trout.

Recent experimental findings indicate that the tadpoles of *L. spenceri* and *L. phyllochroa* are unpalatable to sympatric *G. olidus* and *G. bispinosus*, but palatable to trout (Gillespie 1997). It was also found that survival of *L. spenceri* and *L. phyllochroa* tadpoles was significantly reduced in the presence of trout within the stream environment.

All other extant populations of *L. spenceri* persist at densities from one to two orders of magnitude lower than at Bogong Creek (Gillespie and Hollis 1996). Trout occur in all of these streams. They are also present in all streams where *L. spenceri* has disappeared, including lower sections of Bogong Creek (Gillespie and Hollis 1996). The relative abundances of the other three riverine frog species in Kosciuszko National Park are similar to these *L. spenceri* populations. Collectively, these findings and observations suggest that introduced trout have had a major adverse impact upon temperate riverine amphibians in the region.

Kosciuszko National Park is a major conservation reserve for southeastern Australia; however, the biodiversity of the region has been poorly documented. This survey has added significantly to the knowledge of the frog fauna in the Park. In particular it has uncovered new information on the occurrence of two poorly-known endangered species, *L. spenceri* and *L. booroolongensis*, in New South Wales. In addition, it has provided further insight into the possible causes of declines of temperate riverine amphibians. Further investigation is required to assess the full impact of modified flow regimes and introduced fish upon amphibians in Australia. The influence of these factors upon maintenance of amphibian assemblages should be seriously considered in catchment management.

ACKNOWLEDGEMENTS

This project was financed by the Heritage Unit, Kosciuszko National Park and the Department of Natural Resources and Environment, Victoria. Graeme Enders, Ken Green and Will Allan provided logistical support. Craig Smith gave advice and assistance in accessing remote sections of various streams. Donna Nunan and Will Osborne helped with survey work. Will Osborne also provided advice on historical locations to survey in the northern section of the Park. Richard Loyn, Graham Pyke and an anonymous referee provided comments on the manuscript.

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